Slide 1

Welcome everyone.
We build Mars Analog bases to solve the problems of landing on Mars with humans.
Can we focus and accelerate those efforts by an order of magnitude or more to meet the demands of Starship?

Slide 2

Abstract

For the last two decades, Mars outpost analogs like MDRS have given generations of researchers access to Mars-like conditions so they may validate procedures, equipment, and capabilities. In addition, the University Rover Challenges have given hundreds of students a working knowledge of robotic engineering. Mars analog studies have also flourished worldwide as other organizations have built facilities and programs to expand practical experience with human exploration.

With Starship, human spaceflight progress in the next two decades will expand a thousand-fold. Will analog simulations keep up with reality? What can accelerate practical simulation to address the scientific, engineering, and procedural challenges of the Mars Age?

The lodestar of space analog studies should be space settlement. It must include measurable and comparable results across projects, and between theory and practice. Modular systems should be created based on the areas of science, engineering, and methodology being evaluated. Industrial simulation best practices can be adapted for Mars analog work. Modular systems can also be scaled to allow participation at any level from high school classes to near-launch space operations. This will create an international talent development funnel to prepare for this thousand-fold increase in capacity. It will also democratize problem solving and participation to maximize the benefits to human civilization.

Modular, repeatable, measurable, affordable, and practical systems can be built in such a way that any concept of operation can be tested, compared, and improved. A common formatting language for design, construction, resolution, and publication can simplify comparisons to find the best methods for practical operations for Mars hardware production.

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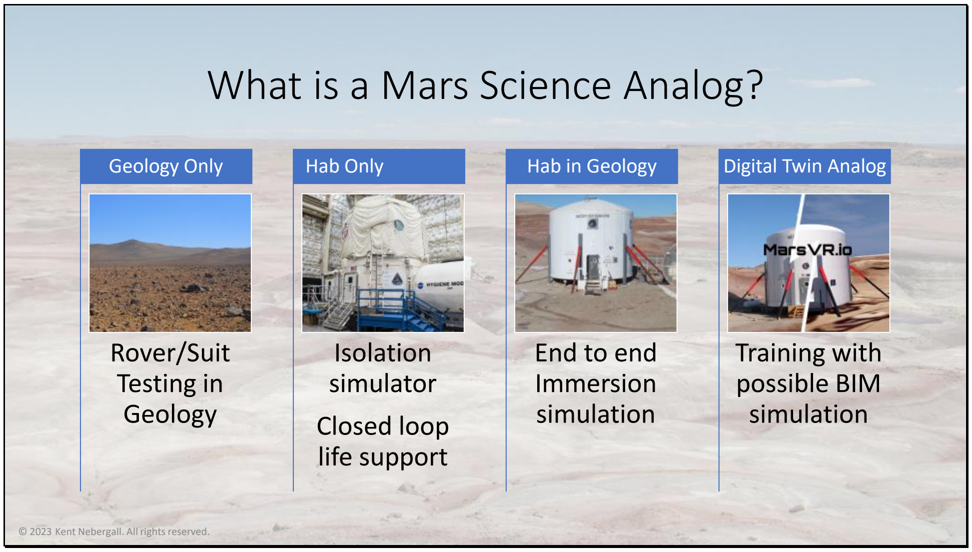

We should first answer, what is an analog? Geology analogs are simply places with Mars-like conditions that may have no facilities. Isolation simulators are indoor analogs. Recently we have digital simulations and digital twins of physical buildings. MDRS is unique in that combines all four elements.

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Simulation Timeline
Accelerating, but Not Fast Enough

Discontinued

Active

Year	Facility/Project	Habitat Design	EVA Facility
1990	**Lunar-Mars Life Support Test (NASA)**	Indoor closed loop life support	None
1991-1994	**Biosphere 2 (original)**	Closed loop massive habitat	Internal EVA
1997-2010	**Desert RATS (NASA)**	Complex camper/rovers and habs	EVA suits, vehicles, habs, robots.
1997	**Haughton-Mars Project (NASA)**	Basic large tent-style hab	EVA, Field Geology
2001	**NEEMO – NASA**	Underwater hab	Diving work
2001	**MDRS and Flashline MARS – Mars Society**	Hab simulation/ workflows	EVA suits, vehicles, habs, robots, VR
2007	**Pavilion Lake Research Project (Canada)**	None	Astronauts run robot subs to find microbes
2009 (500 days)	**Mars500 (Russia)**	Large hab, closed life support loop	Tiny indoor yard
2010	**HI-SEAS (Hawaii)**	Large hab, dome	Open volcanic ara, EVA
2013	**HERA**	Large indoor hab – resources, psychology	None
2014	**SIRIUS (Russia)**	Large indoor hab – resources, psychology	Tiny indoor yard
2017	**LunAres Poland**	(not mentioned)	EVA work
2019	**Analog-1 (ESA)**	ISS	ESA Rover in Desert controlled from ISS
2020	**NEEMO NEMO (NASA)**	NASA underwater hab	Diving work.
2023	**CHAPEA (NASA)**	3D printed indoor habitat	Tiny indoor yard
2023	**SAM – BioSphere 2 Adjunct**	Closed loop life support habitat	Covered Mars yard with pressurized EVA.

Originally, NASA used geology analogs for training Apollo astronauts to walk on the moon.
NASA ran a few studies in the Nineties, and Biosphere 2 was built.
When MDRS opened, it had a bit of a monopoly for nearly a decade.
Then about a dozen years ago, new analog operations began to appear worldwide. There are currently ten operational facilities. Over a thousand scientific papers cite MDRS alone.

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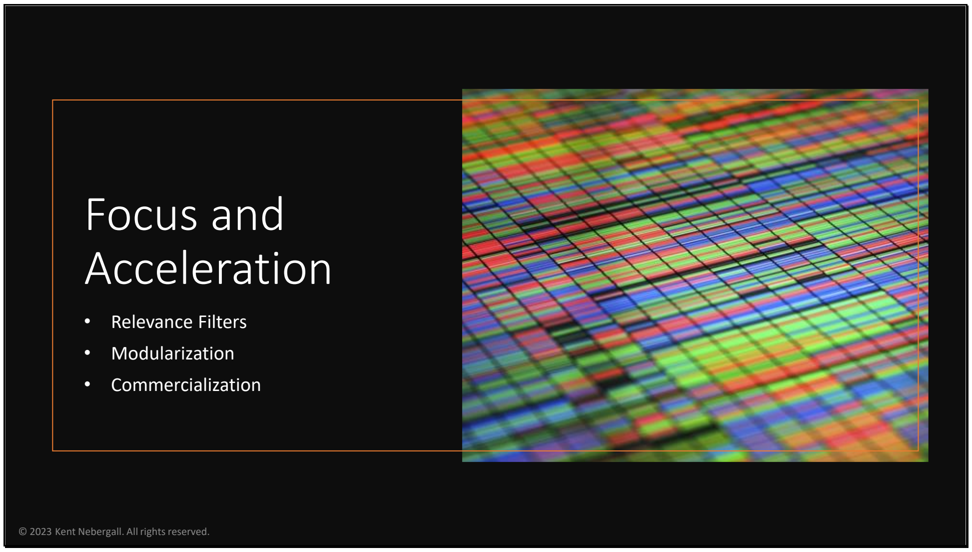

So, what can be done to accelerate Mars Exploration and settlement?
We need to focus on relevance, modularization, and eventual commercial systems where appropriate.
While I believe this is a good model for the Mars Technology Institute, I'm keeping this presentation generic so any organization could pick it up as a best practice roadmap.

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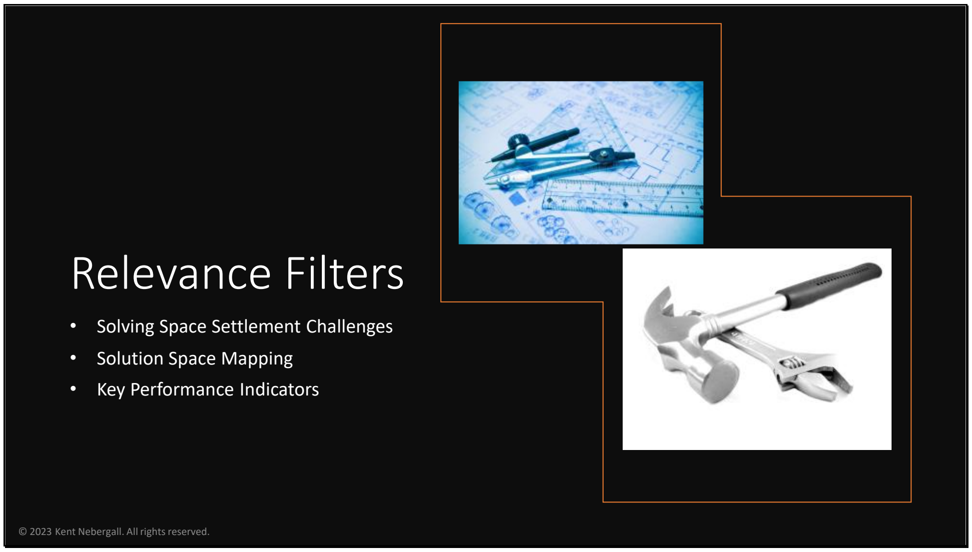

First, are we asking the right questions? What do we need to learn before going to Mars?

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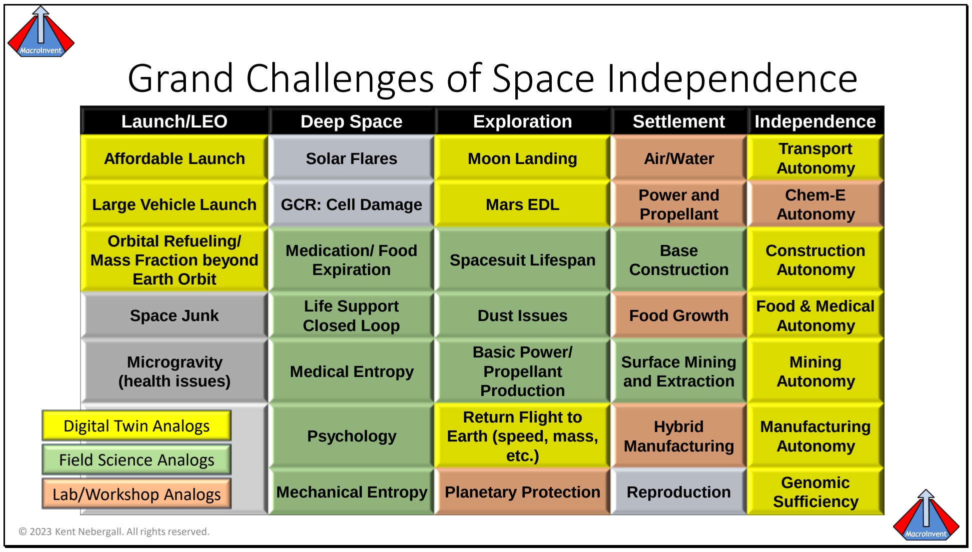

Here are the grand **challenges** of space settlement and **independence**.
The items in **green** can be simulated to some degree in **Earth-based analog** habitats. Items in **yellow** can be simulated with **digital twins or other modeling** systems.
Items in **gray** like space junk are largely **limited to studies in space**.
Research at a Mars analog, by definition, should focus specifically on one or more of these space settlement challenges.
Any facility work should move our body of scientific and engineering tools closer to being multiplanetary.

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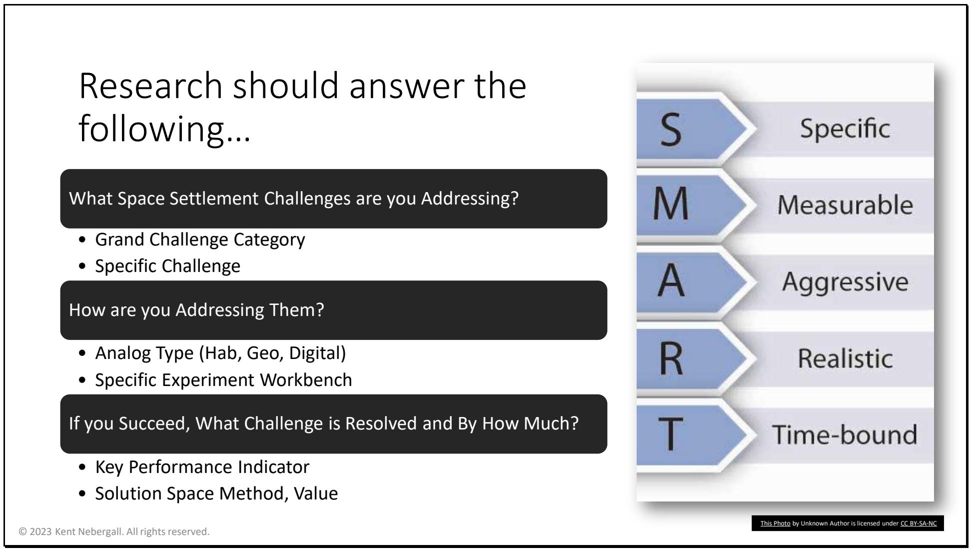

Any research proposal should have key performance indicators mapped back to a specific challenge of space exploration and settlement.
As with business projects, we need SMART Goals, which are Specific, Measurable, Achievable, Realistic, and Time Bound.

So that said, research at a Mars analog should focus specifically on one or more of these space settlement challenges.
It should spell out how it plans to expand the solution space of science and engineering against the problems of living on Mars.
While we often use facilities for education, outreach, remember that a Mars Analog that isn't relevant to getting to Mars is just cosplay.

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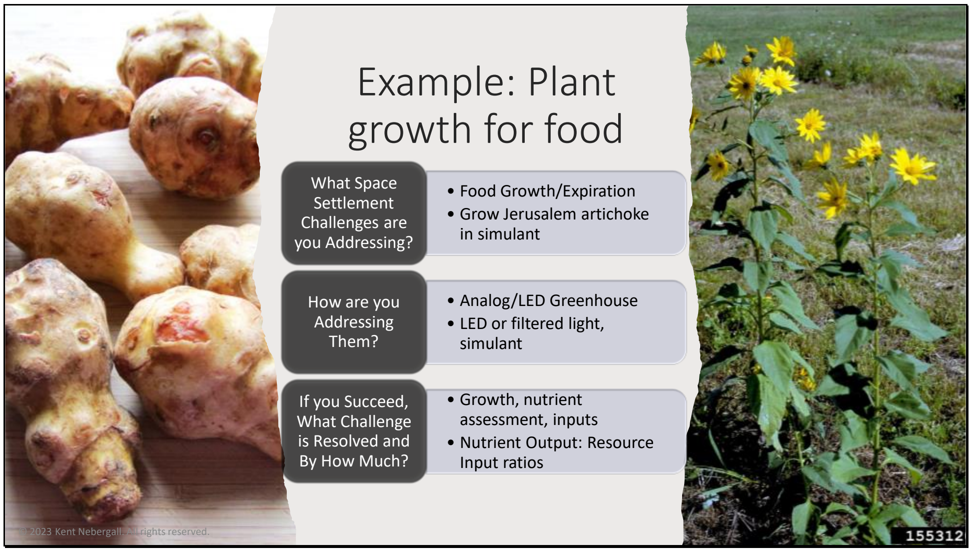

Let’s take a simple example. We need to grow food on Mars, and there are alternatives to Potatoes.
Jerusalem artichokes are almost as good as potatoes but can grow in poor, sandy soils.
We could grow them under Mars-like lighting conditions, measure watering and plant food in a sand soil base, then assess the quantity and quality of the foodstuffs.
We can map this all back to the three questions on the previous slide.

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Second, we need consistent documentation before, during, and after the simulation.
Proposals should use a common template. While academic research proposals have standard formats, those can be included as one option with a cover sheet that deals with Mars analogs. This cover, for any work, needs to explain how it accelerates Space Settlement, and by how much.
During the mission, a scientific lab notebook software package should be used for science and engineering data.
Finally, results should be published and tracked, and a report on how well the simulation met the standard Mars Settlement Metrics must be returned.
We can then map progress for the facility on a dashboard.

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A key aspect of any tech revolution is a modular set of tools that explodes in popularity, so that thousands of projects fill the trade space. After best practices are refined, the most successful solutions are normalized.
I found three good examples from which we can cherry pick features for our ideal Mars Analog lab setup.
By combining them, we can dramatically increase the quantity and quality of our science and engineering solutions.

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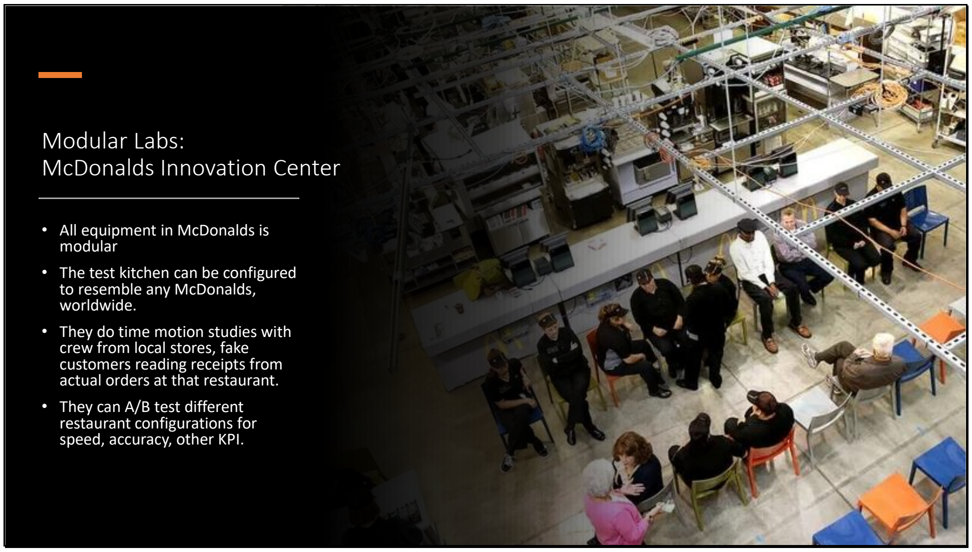

First is a place called the McDonalds Innovation Center in Illinois. There are roughly 40,000 McDonalds restaurants worldwide, and they all use modular kitchens. Most swap the grills around every day between breakfast and lunch. This research facility can be configured in an hour or so to have the same layout as any store kitchen worldwide. New modules can be optimized before they ever get into a restaurant (except the ice cream machine, apparently). They then drill through actual orders from sales records with pretend staff to optimize workflows.

We make modular labs for analog studies work the same way? They could be plugged in, reconfigured, and be supplied with uniform consumables. Lab work can be recorded consistently.

A setup like MDRS could have a dozen such stations optimized for geology, biology,

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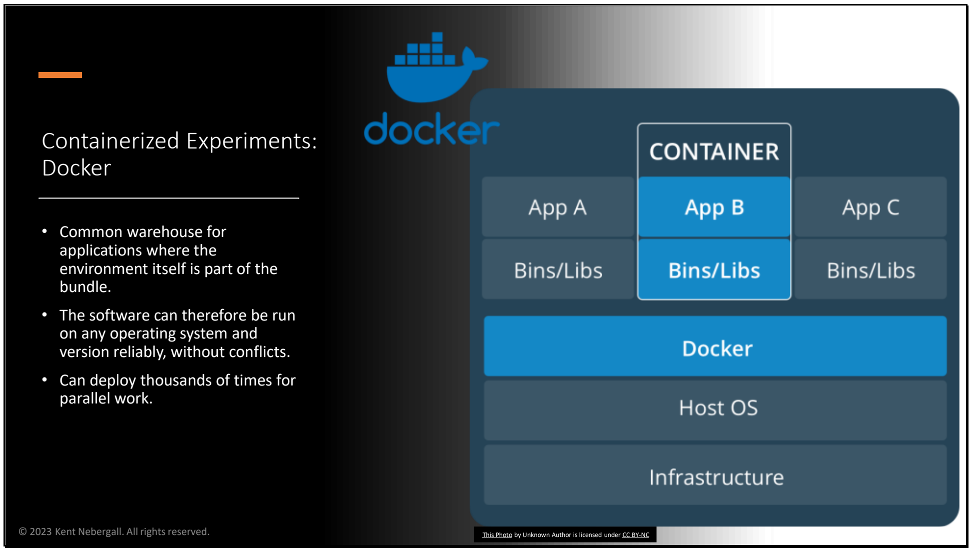

Our second inspiration piece is Docker, which is a platform used on application servers. Software packages run cleanly and reliably because each is bundled with the components they need, and they are isolated from the operating system. Many Docker containers are freely available as open source. You can run lots of them simultaneously.

If we combine this concept with the Modular Labs, we can run experiments the same way – a bit like a pod coffee maker.

Simply bundle a compatible set of equipment and consumables, along with detailed instructions. Now let's shift from physical bundles to informational ones.

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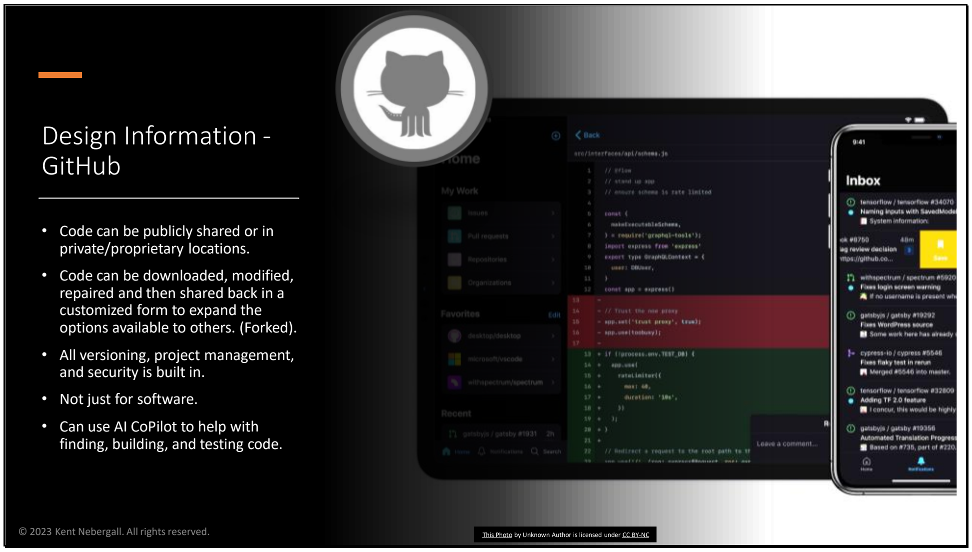

Lastly, we have GitHub. This is a massive software component library used by developers worldwide. They use GitHub to find pieces of code to incorporate into their projects. They can then improve or customize them and return variations of them to the GitHub library, thus expanding the solution space. These libraries can be open source or private. Project management software is built in.

Imagine something like GitHub, but specifically for experiment designs, scientific papers, and so on.
We could apply open-source methods to equip thousands of analog researchers worldwide.
Also, Peer review becomes easy with the experiments swapped in and out of lab workstations by students and staff.

As with software branching in GitHub, scientists and engineers can tune new experiments to increase our data sets within a given grand challenge trade space.

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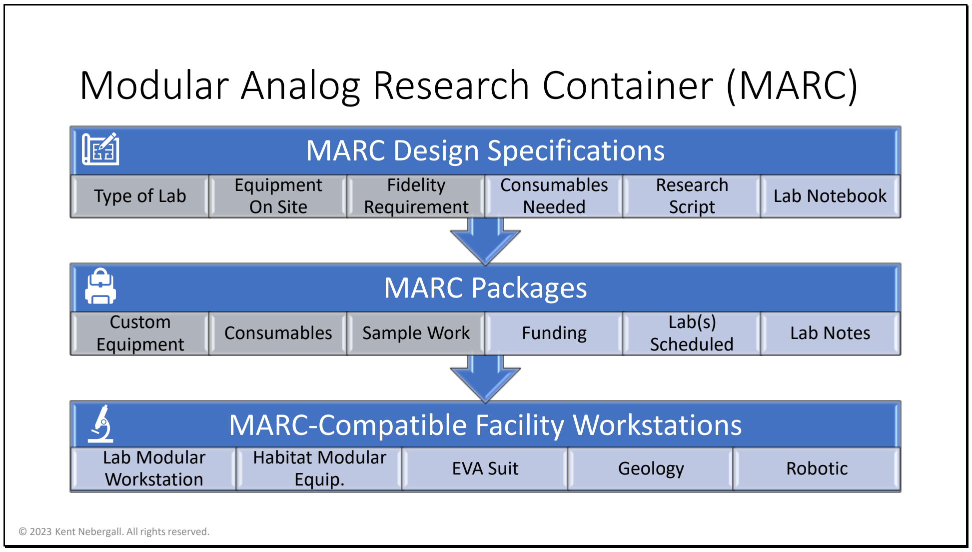

So let's combine this into a single system called MARC, or Mars Analog Research Containers.
We have a design layer for the experiments, where the guidelines are simply filling out an online form.
We have bundles of the physical consumables, sample returns, funding, and scheduling of the lab work. Basically anything that costs time and money, goes in the lab, ships in a box, and gives experimental results.
Finally, we have the facility workstations that can load, document, and swap out these experiment packages.

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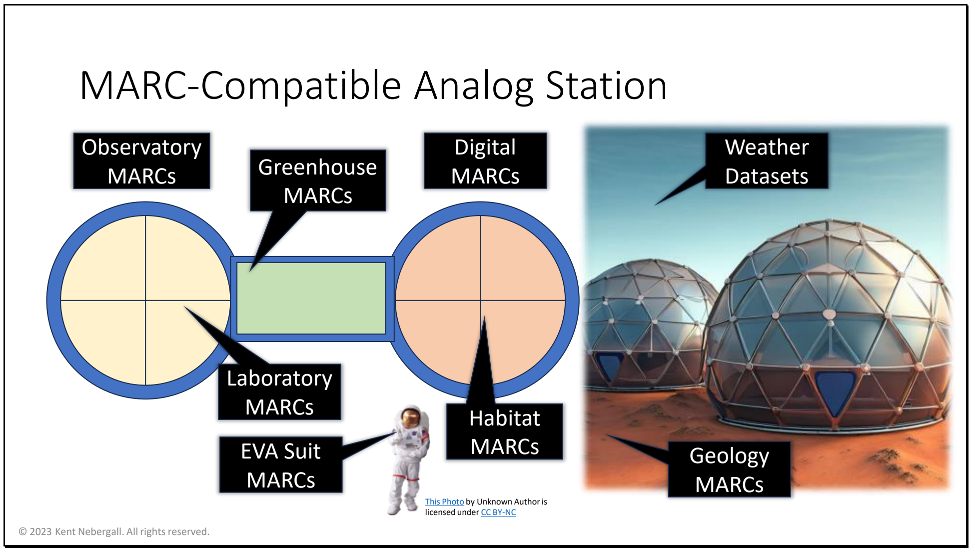

The modular labs are specialized in geology, robotics, agriculture, or whatever is needed to solve the grand challenges. This includes the habitat itself and its environs. Labs may be low fidelity like high school cubicles or high fidelity like NASA environment chambers. The level of fidelity would have a rating system, similar to the NASA Tech Readiness Level concept. Experiments would have a minimum TRL rating required to run the experiment.

So picture a building with workstations for biology, geology, and so on. The greenhouse, EVA suits, and other systems are also considered MARC modules. Furthermore, the habitat itself would be modular to reconfigure and optimize living conditions and simplify maintenance. Observatories and known geologic deposits can be listed like workstations.

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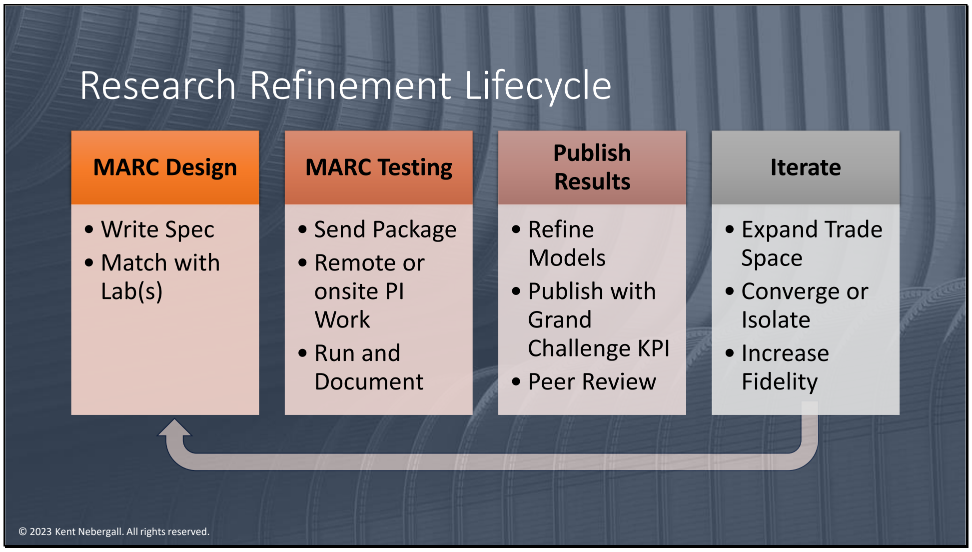

The Research Refinement Lifecycle begins with designing a MARC. If it is approved and funded, the test packages can be built and sent to facilities or used locally in the network. After the simulation, the results are published and rated for accuracy with peer reviews and proof of repeatability experiments. Finally, the data is entered in a trade space and other variants are suggested back to the Design process to find the best combinations.

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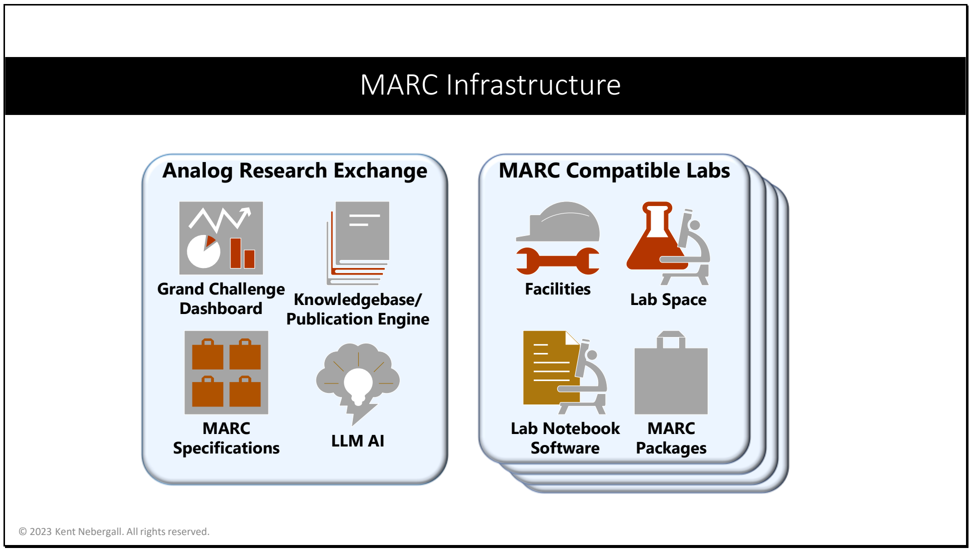

So we have two main systems to build.

The Analog Research Exchange keeps a Mars Settlement dashboard, library of past research and other sources, defined MARC specifications, and an AI for easy searches and summaries. It can work with MARC compatible labs worldwide to distribute experiment designs for customization and publication. Note that a large facility may host its own exchange, but we should use common data formats for easy knowledge pooling.

Second, the network of MARC compatible lab workstations would be classified and rated, so that an efficient mix of quality experiments and facilities can be kept running worldwide at peak efficiency. Earlier, simpler experiments could be done in cheaper labs, with the highest cost ones reserved for complex experiments.

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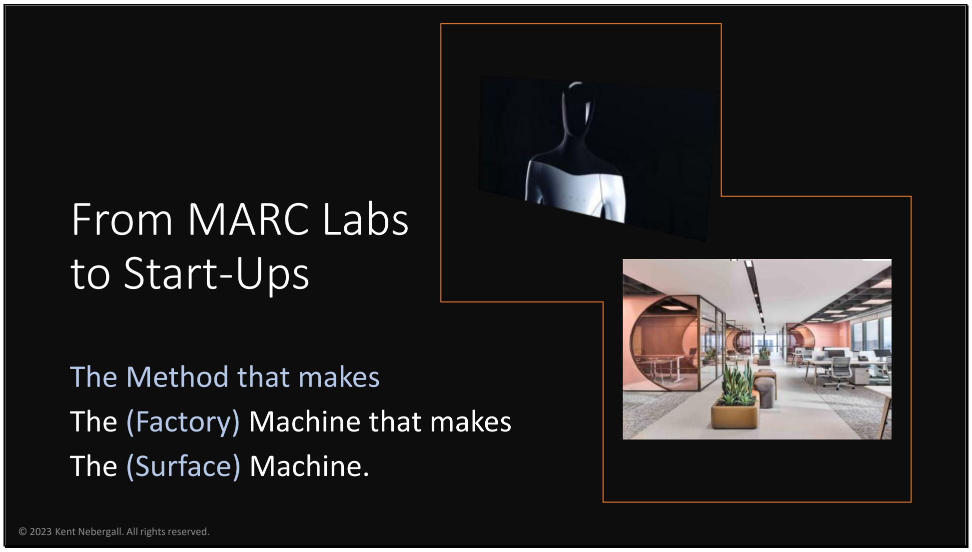

So with all that done at the lab workbench level, lets consider what a business Start-up incubator built on the same principles would look like.

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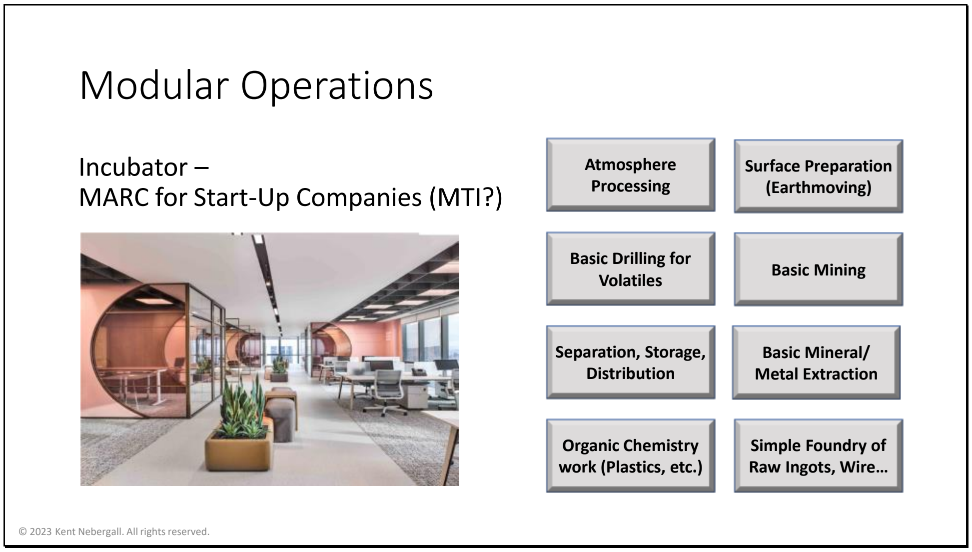

The purpose of a start-up, like an experiment, is to solve a problem with a consistent, provable method.
Each business plan needs to solve a grand challenge problem to be considered. But it also needs to have a business model that works on Earth. Otherwise, it will go bankrupt before it becomes relevant for the future space economy.

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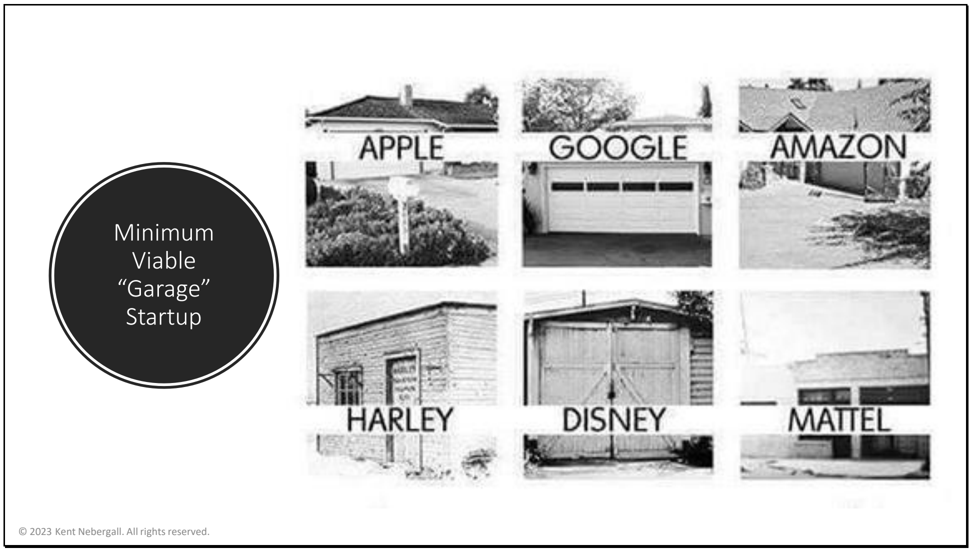

Remember all these massive businesses started in these garages. We can **add the Wright Brothers** and other examples to this list.
We know massive companies can be launched in small facilities. But what else does it take?

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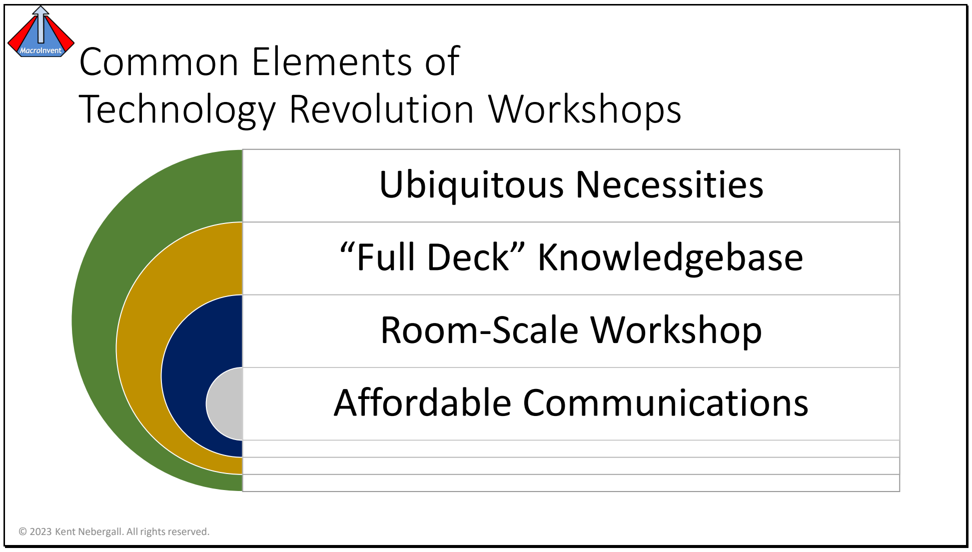

Technology revolution workshops throughout history have common elements.
First, you need to be able to take for granted things like food, power, shelter, and other infrastructure.
Second you need a tool set that is both easy to understand and incredibly powerful. These tool sets become the physical language of the technology revolution.
Third, you need to be able to fit the workshop and the team within speaking distance of each other.
For digital products, you also need unlimited ability to distribute and market your arts and sciences.

All this is like the MARC lab workbench, but scaled up to a workshop the size of a three-car garage.

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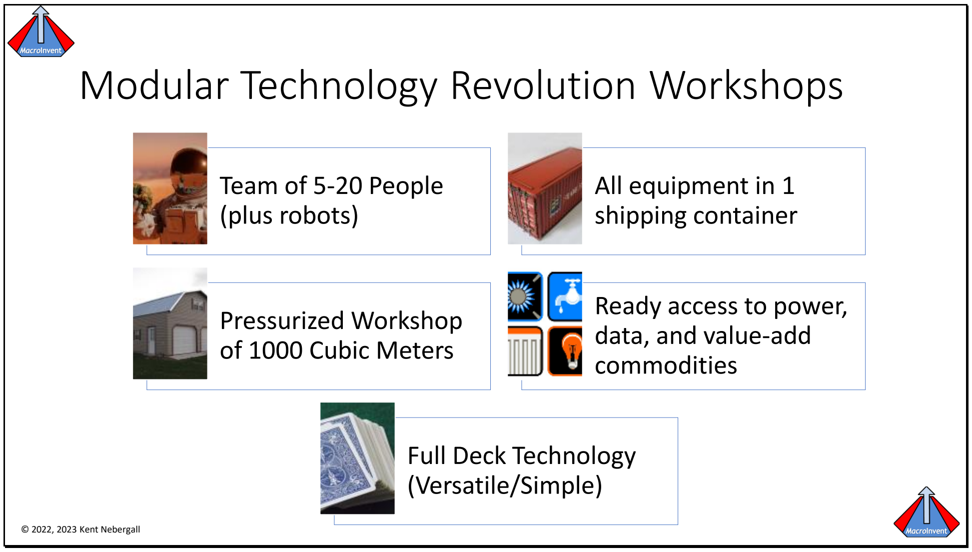

These **modular workshops** are scaled to fit in a **SpaceX Starship**.
To qualify, this operation must be a small team with one shipping container's worth of tooling. They must be able to operate in a pressurized space the size of a two-car garage. They must have easily repaired and upgraded equipment that operates efficiently.

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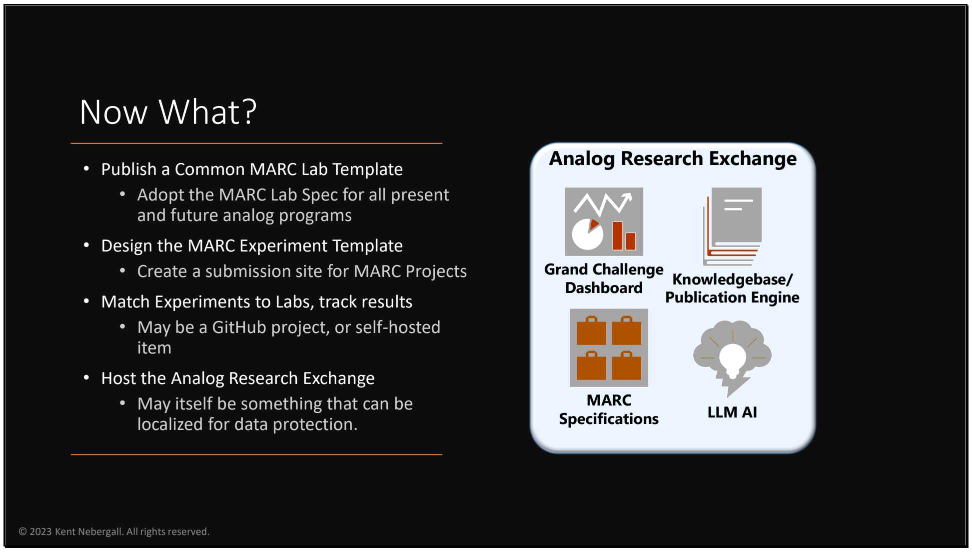

So how do we start?
First, we need templates for MARC experiments. From there, we can make compatibility specifications for lab racks. A standard taxonomy for the Grand Challenges is also needed, along with Key metrics for each.
Hosting a central operation would be easy. Although once the system is designed, it can be open sourced for local exchanges like universities. We can then launch a connection service for labs, projects, and investigators.

I'm proposing this as a toolbox for the Mars Technology Institute, but it's designed to be – well – modular. Any university, organization, or business worldwide can pick up the parts that work for them.

Let a thousand analog flowers bloom. We'll need them. The Mars age is finally approaching, if we open the doors.

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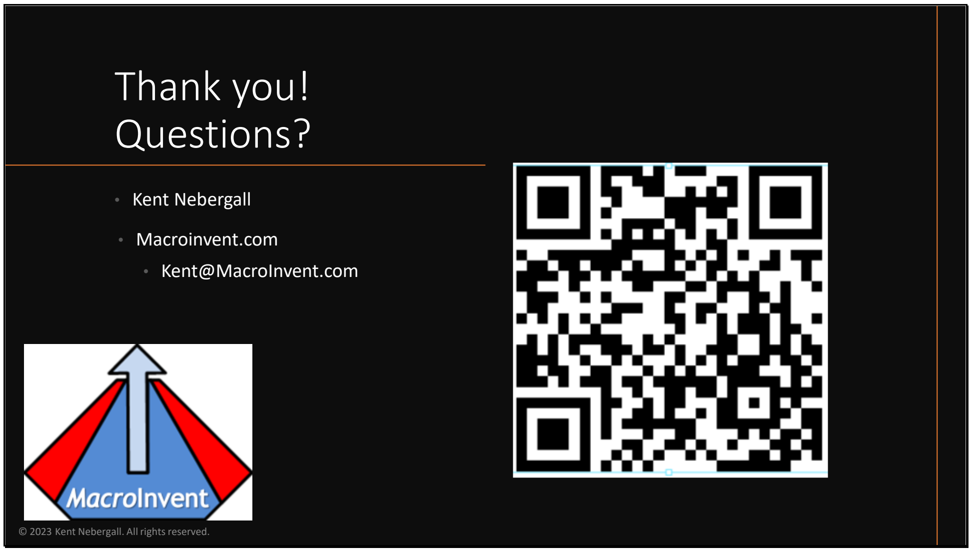

Thank you! Any questions?

If you want to see my presentations for the last 15 years, including this one, the QR code links to my portfolio web site. Contact me from there as well if you want to work on this.